BEFORE THE
FEDERAL COMMUNICATIONS COMMISSION
WASHINGTON, D.C. 20554

In the Matter of	)	
	)	
Establishment of Interference Temperature Metric to Quantify and Manage Interference and to Expand Available Unlicensed Operation in Certain Fixed, Mobile and Satellite Frequency Bands	)	ET Docket No. 03-237

COMMENTS OF INMARSAT VENTURES LTD

John P. Janka
Alexander D. Hoehn-Saric
LATHAM & WATKINS LLP
555 11th Street, N.W., Suite 1000
Washington, D.C. 20004-1304
(202) 637-2200

Its Counsel

Paul M. Deedman
Senior Frequency Coordination Engineer
Inmarsat Ventures Ltd
99 City Road
London EC1Y 1AX
United Kingdom

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Table of Contents

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	)	
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COMMENTS OF INMARSAT VENTURES LTD

Inmarsat Ventures Ltd ("Inmarsat") welcomes the opportunity to comment on the Commission's Notice of Inquiry and Notice of Proposed Rulemaking. Inmarsat has participated in the joint comments of almost a dozen satellite operators filed in this proceeding, and is writing separately to provide an analysis of certain assumptions that the Commission has made in its proposals, as well as to elaborate on a number of issues addressed in the joint comments of the satellite industry.

1. Introduction and Summary

Inmarsat has two separate, but related, interests in this proceeding. First, Inmarsat uses the 6525-6700 MHz part of the C band for Fixed Service Satellite (FSS) links to its Mobile Satellite Service (MSS) network, and therefore is subject to interference from any new uses of this frequency band. Second, a number of issues in this proceeding are substantially the same as those that are being debated in rulemaking and licensing proceedings concerning the deployment of ATC in the L band.

Inmarsat has joined numerous FSS and MSS satellite companies in questioning whether the proposed interference temperature approach is feasible, and whether it would achieve the Commission's goals. As detailed below, Inmarsat believes that the Commission's proposals pose a far greater interference threat to FSS operations than reflected in the NPRM, because a number of assumptions underlying the proposals do not appear to be founded and many in fact appear not to be capable of ascertainment. These assumptions relate to: (i) the level of interference that satellite systems should be able to accept from unlicensed devices, (ii) the typical coverage pattern of satellites, (ii) how unlicensed devices will be deployed, and (iv) the characteristics of the unlicensed devices that are deployed.

2. Background

Inmarsat currently operates a network of 9 geostationary satellites which together provide nearly global coverage. Several of the satellites locations are "visible" from the United States. Inmarsat is currently in the process of procuring its next generation of Inmarsat 4 satellites for launch in 2004 and 2005, one of which will be "visible" from the United States. These satellites operate in bands that include the 6525-6700 MHz portion of the C band, which is the subject of this proceeding.

Inmarsat's C-band uplinks are used for a number of mission-critical purposes:

1. As feeder links for Inmarsat mobile satellite services for which the downlink band is 1525-1559 MHz. This includes the links which provide Inmarsat's services as part of the Global Maritime Distress and Safety System (GMDSS) which provides safety-of-life services to the maritime community throughout the world;
2. As feeder links for Satellite Based Augmentation System (SBAS) signals which are part of the Radionavigation Satellite Service (RNSS). These are used to enhance GPS capability (integrity as well as improved accuracy and availability), used for example for aircraft navigation purposes. Such signals are used in the United States in support of the FAA's Wide Area Augmentation System (WAAS);
3. As uplinks for C-band downlinks, used as communication channels for Inmarsat's network control. This includes functions such as call monitoring which is used as part of the billing process;
4. As uplinks for telecommand and control. These are used to monitor and control the satellite and its payload - each one worth hundreds of millions of dollars.

All these functions are of major commercial significance to Inmarsat and its end users, and in some cases relate to safety-of-life services. Therefore it is of critical importance to Inmarsat that these functions are not jeopardized by interference. Furthermore, it should be noted that in the case of Inmarsat communication services, wide band interference in the uplink, as can be envisaged from the large scale deployment of unlicensed devices, has the potential to affect many users simultaneously.

As the number of users and traffic carried by Inmarsat's network has expanded, the amount of FSS spectrum required for feeder links, network control links and TT&C links has also expanded. This growth is likely to continue in the future. Due to congestion in other parts of the C band, Inmarsat is likely to increase its use of the band 6525-6700 MHz in particular. Due to its concern over possible interference to Inmarsat satellites in the band 6525-6700 MHz, Inmarsat's comments concentrate in particular on the Commission's proposals for this band.

3. Parameter Values for Use in Calculating Interference Temperature

All Inmarsat satellites are of the "frequency translation" type (i.e. the uplink signal is translated to the downlink frequency without demodulation). Hence, the aggregate interference received at the receiving earth station includes both interference received by the satellite which is re-transmitted and interference received directly by the earth station.

In paragraph 38 of the NPRM, the Commission seeks comment on the various assumptions made in its link budget analysis appearing in Appendix B. In Section 3.1 below, the parameter values describing the satellite system are discussed. In Section 3.2 below, the $\Delta T/T$ criterion is discussed.

3.1 Satellite Systems Parameter Values

The C band antennas used on all Inmarsat satellites are designed to give "global" coverage – that is to provide roughly constant gain across the visible earth surface. For these antennas, the peak gain is about 22 dBi. This is lower than the value assumed by the Commission; however, this value is related to the "percentage of CONUS in one beam." The Commission assumes that only 75% of CONUS is in the satellite beam. This may be appropriate for a high gain/narrow beam antenna, but is not appropriate for low gain, "global" antennas. In fact, as illustrated in Figure 1 below, in the case of the Inmarsat AOR spacecraft at 53° W.L., the United States forms only a fraction of the visible land mass, which includes all of South America, and a large portions of North America, Africa and Europe.

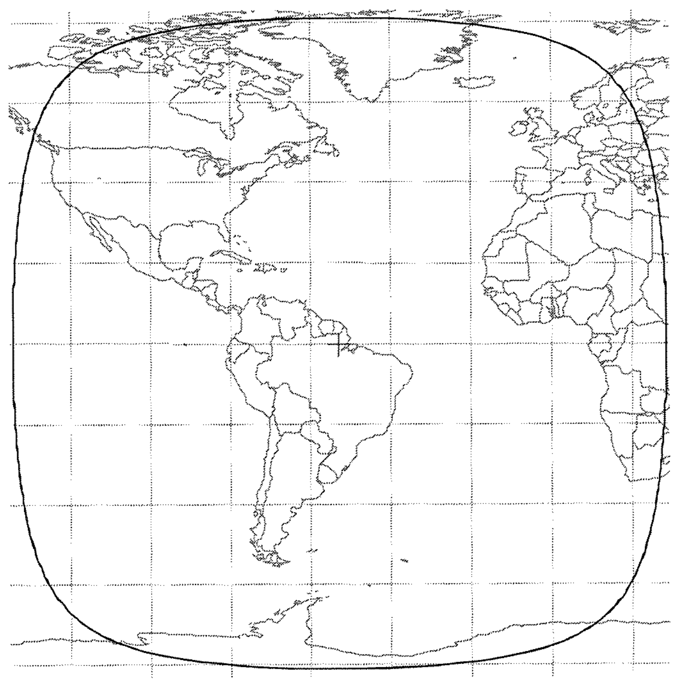

FIGURE 1

Visible earth from GSO satellite at 53° W (Plate Carree projection). The solid black line shows visibility limit

Moreover, any analysis of the level of interference that a satellite system may be expected to tolerate must account for interference in the satellite uplink from terrestrial systems not only in the United States, but also in almost all visible countries. Hence, the aggregate interference from terrestrial uses in the United States should be a fraction of the total interference which can be accommodated by the satellite system. For satellite systems which employ global beams, it would be appropriate to apportion about 20% of the total interference allowance to the terrestrial uses in the United States.

Although the Inmarsat satellite antenna gain is lower than the value assumed by the Commission by a factor of about 10 dB, this is balanced by the necessary and related assumptions that (i) all of CONUS is within the coverage of the satellite beam, and (ii) CONUS constitutes only a small portion of the visible land mass. Overall in this respect, the sensitivity of the Inmarsat satellites to terrestrial interference is similar to the sensitivity assumed by the Commission.

3.2 ΔT/T Criterion

The Commission posits that the new services proposed under the interference temperature concept would make use of unused margin and that this would benefit the licensed service by setting a well defined "interference temperature cap." In the example discussed in paragraph 15 of the NPRM, the unlicensed devices would be able to take advantage of the increased carrier power that exists when a receiver is relatively close to its transmitter. By ensuring that the additional interference does not degrade the margin at the point where the wanted service is on the cusp of availability, it "would assure that the licensed operation would not experience any further degradation or loss of service from new interference."[1] The example appears to be most applicable to a terrestrial broadcasting scenario.

As elaborated below, in the particular scenario posited in the NPRM where interference may be caused to the satellite receiver, this concept simply does not apply. In a satellite system there is no identifiable group of users or identifiable geographic area for which users have excessive margin which can be used to accommodate new spectrum users. Any increase in the aggregate interference margin would degrade service for many if not most satellite users.

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[1] NPRM at para. 15.

As the Commission indicates, the traditional criterion for coordination between satellite systems is a ΔT/T criterion of 6%. This value is compared to the increase in system noise temperature due to the contribution from another satellite network. Where the other network causes interference in both the uplink and downlink, the aggregate interference is determined and compared to the 6% criterion. This is a different situation from the one addressed here, which involves interference from *terrestrial* services into satellite systems which operate in the FSS, MSS and RNSS and for which interference there is no coordination process.

The interference being considered here is from an aggregation of a large number of terrestrial transmitters. It is therefore reasonable to assume that the total interference will be effectively constant, or "long term." Inmarsat link budgets include a long term interference margin of 1 dB and this value is commonly used in both the FSS and the MSS. An additional "short term" margin is generally included to account for short term propagation impairments. To conserve mobile terminal power and satellite power, and to reduce intermodulation effects, power control is used to set the uplink carrier power at the minimum level that will ensure that the availability and performance requirements are just met. Hence, long term interference which led to a loss of margin of more than 1 dB would quickly lead to significant degradation of the link performance and availability.

In this regard, Inmarsat emphasizes that satellite systems are not designed with large margins in their link budgets.[2] Satellites are generally limited in their total e.i.r.p. largely due to the available power. Therefore an increase in link margin may often have to be at the expense of the satellite's overall traffic capacity. Hence link margin is a very expensive commodity in a satellite system. Due to the limited spectrum available for FSS services, satellite system operators have every incentive to migrate to more technologically innovative and efficient

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[2] *Compare* NPRM at para. 25.

uses of spectrum, for example through the use of high order modulation schemes and through adaptive coding techniques. Such methods lead to a requirement to increase the carrier-to-noise ratio to meet the more demanding receiver requirements and thus further restrict the power that can be made available to accommodate increased interference. Satellite operators have every incentive to achieve the greatest possible level of performance from their equipment, because, among other things, excess weight has a direct impact on the cost of launching a spacecraft, and all electrical power consumed on a spacecraft needs to be generated on board from solar panels.

The interference margin in Inmarsat's link budget is intended to accommodate interference from the following external sources:

1. Other MSS systems (including interference from other Inmarsat satellites) which contribute downlink interference to the mobile earth stations in the band 1525-1559 MHz;
2. Other RNSS systems which contribute downlink interference to the earth stations in the band 1559-1610 MHz;
3. Other FSS systems (which produce interference in the feeder uplink and, in the case of the C-to-C links[3], in the downlink direction also);
4. Other services in the uplink band, which, in the band 6525-6700 MHz consists of the fixed and mobile[4] services;
5. Other services (i.e. not FSS, MSS or RNSS) internationally allocated in the downlink bands, which differ from band to band as follows:
    a. In the case of downlink band 1525-1559 MHz, there are different services in different Regions and in different portions of the band, including fixed, mobile, earth exploration satellite, space operation (space-to-Earth);
    b. In the case of the downlink band 1559-1610 MHz, this is allocated to the radionavigation satellite service, the aeronautical radionavigation and fixed services;

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[3] C-to-C links are those for which both the uplink and the downlink are in C band FSS spectrum

[4] The mobile service is allocated internationally and hence mobile systems outside the United States may contribute to the received interference.

c. In the case of the downlink band in C band spectrum (in the range 3550-3955 MHz), this is allocated to the fixed, amateur, mobile and radiolocation services; and

6. Other services in nearby frequency bands which may contribute to the aggregate interference through their out-of-band emissions.

Thus, there are numerous possible sources of external interference. Some sources of interference can be predicted and controlled, for example through inter-satellite network coordination procedures, but it is often necessary to accept more interference than would be desired to obtain the necessary coordination agreements. Other sources cannot be predicted or controlled, for example interference from terrestrial services, but an interference margin allowance can be made to accommodate interference from existing and future licensed devices. Considering either case, it is unjustifiable to assume that there is excessive interference margin available to accommodate new, unlicensed interference sources. Inmarsat therefore believes that the interference temperature concept is not suitable for the bands at issue, which are allocated to space services in the uplink direction.

If the Commission were to base an interference temperature limit on a $\Delta T/T$ threshold[5] criterion, a concept that Inmarsat does not support, it would be necessary to apportion the available interference margin among those different sources. ITU-R Recommendations are a good source of guidance in this respect. ITU-R Recommendation S.1432[6] gives guidance on the apportionment of the available interference margin. Recommends 3 states:

> 3 that, when sharing frequencies below 15 GHz, the maximum allowable interference from all sources (aggregate) should be limited to 32% or 27% for systems not practising and for systems practising frequency re-use, of the clear-sky satellite system noise.

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[5] NPRM at para. 15.

[6] Recommendation ITU-R S.1432; "Apportionment Of The Allowable Error Performance Degradations To Fixed Satellite Service (FSS) Hypothetical Reference Digital Path Arising From Time Invariant Interference For Systems Operating Below 15 GHz," 2000.

Because all Inmarsat spacecraft employ frequency re-use, the 27% figure is appropriate. An I/N value of 27% is equivalent to a loss of margin of approximately 1 dB and hence this aggregate criterion is consistent with the interference margins used in Inmarsat link budgets.

In the same recommendation, Recommends 4 states:

> 4 that error performance degradation due to interference at frequencies below 15 GHz should be allotted portions of the aggregate interference budget of 32% or 27% of the clear-sky satellite system noise in the following way:
>
> – 25% for other FSS systems for victim systems not practising frequency re-use;
> – 20% for other FSS systems for victim systems practising frequency re-use;
> – 6% for other systems having co-primary status;
> – 1% for all other sources of interference.

Taking this Recommendation into account, the following interference apportionment is appropriate:

Source	**I/N (%)**	**I/N (dB)**	**loss of margin (dB)**
Other FSS/MSS/RNSS networks	20	-7.0	0.79
Other co-primary services	6	-12.2	0.25
All other sources	1	-20	0.04
Total	**27**	**-5.7**	**1.04**

TABLE 3 Interference apportionment among different services

The fixed and mobile services being analyzed for Part 15 operation in the band 6525-6700 MHz fall into the category of "other co-primary services," and an I/N criterion of 6% is appropriate for all such co-primary services, of which the Part 15 devices would be but a subset.[7] In addition to the unlicensed fixed and mobile devices being analyzed in this band, there will be interference contributions from other sources which also fall into this category; namely the *licensed* terrestrial services in this band, plus the interference from other co-primary services in

[7] This contrasts with the appropriate ΔT/T for ATC in the L-band, which, as a secondary service, is appropriately accounted for, at most, within the 1% margin for "all other sources." *See, e.g.*, Inmarsat Opposition to Petition for Partial Reconsideration and Clarification of Mobile Satellite Ventures Subsidiary LLC, IB Docket No. 01-185, at 9-11 & nn. 31-35 (filed August 20, 2003).

the downlink band. The other co-primary services in the downlink band vary between the different bands. However, it would not be practical to apply different criteria to the uplink interference depending on the downlink band and it is therefore desirable to have a consistent apportionment of interference. For this reason, the 6% criterion would need to be apportioned between uplink interferers and downlink interferers, and between licensed and unlicensed systems. In such a case, the only rational approach would appear to be to apportion this criterion equally between uplink and downlink interference, and then further subapportion the uplink interference into licensed and unlicensed devices. In bands for which a terrestrial fixed and mobile co-primary allocation exists, this would lead to a value for Part 15 devices of no more than $\Delta T/T = 1.5\%$. The Commission's 5% value therefore does not appear to be founded. For purposes of analyzing the Commission's assumptions about the number of potential unlicensed devices that could be supported in the bands in question, Inmarsat uses a $\Delta T/T$ of 1.5%. More fundamentally, however, and as reflected in the comments of the satellite industry in which Inmarsat has joined and in its own comments above, Inmarsat does not believe that the "interference temperature" concept is appropriate for the bands in question.

4. Calculation of Power Limits on Unlicensed Devices

In this Section, Inmarsat analyzes the Commission's assumptions about the number of unlicensed devices that might be supportable in the bands under consideration. In Section 4.1, Inmarsat examines the estimation of the average interfering power from unlicensed devices. In Section 4.2, Inmarsat examines the total number of devices which just meet the interference criterion. In Section 4.3, Inmarsat discusses the necessary power restrictions that would permit large numbers of unlicensed devices.

4.1 Calculation of Average E.I.R.P. From Unlicensed Devices

In Appendix B of the NPRM, the Commission provides the assumptions used to estimate the average e.i.r.p. from each unlicensed device. Although the detail of the calculation is not given, it is apparent from the figures in the large table in Appendix B that the average e.i.r.p. from each unlicensed device is the parameter labelled "Transmit EIRPs from Aggregate Interfering Devices" and has the value -24.08 dBW. The table below shows Inmarsat's calculations, based on the Commission's assumptions.

	Mobile devices duty cycle (10%)				Fixed Devices 100% duty cycle	
EIRP (mW)	50	100	200	1000	2000	4000
Device distribution	30	35	20	5	5	5
Number in simultaneous transmissions at specified e.i.r.p.	3	3.5	2	0.5	5	5
Antenna discrimination to sat (dB)	-6	-6	-6	-6	-21	-21
e.i.r.p. towards sat (from outdoor devices) (dBm)	15.8	19.4	20.0	21.0	19.0	22.0
e.i.r.p. towards sat (from indoor devices) (dBm)	5.8	9.4	10.0	11.0	9.0	12.0
sum indoor and outdoor devices (dBm)	16.2	19.9	20.4	21.4	19.4	22.4
sum indoor and outdoor devices (mW)	41.4	96.7	110.5	138.2	87.4	174.8
aggregate e.i.r.p. towards sat from 200 devices (mW)	649.0					
ave. e.i.r.p. from one device (mW)	3.2					
ave. e.i.r.p. from one device (dBW)	**-24.9**					

TABLE 4 Average e.i.r.p. per unlicensed device based on the Commission's assumptions

Inmarsat's calculations result in a similar, but slightly smaller value for the average e.i.r.p. towards the satellite from a single device which provides some confidence that it has made the same assumptions as the Commission in calculating this figure. The resulting value is dependent on a number of assumptions, including the assumed distribution of indoor versus outdoor devices, the assumed duty cycle of the devices, the assumed distribution of e.i.r.p., and the assumed antenna discrimination towards the satellite.

It is clearly not possible to accurately predict (or control) the distribution of power, duty cycle and location of future unlicensed devices. However, it is interesting to examine the sensitivity of the results to certain assumptions. For example, if the e.i.r.p. distribution of the 100 mW and 1000 mW mobile devices is reversed (i.e. that 5% of devices are assumed to have an e.i.r.p. of 100 mW and 35% of devices are assumed to have an e.i.r.p. of 1000 mW), the resulting average e.i.r.p. from one device is -21.6 dBW, an increase of 3.3 dB. This is equivalent to reducing the acceptable number of devices by over one half. Due to the potential impact of these assumptions, any calculation of interference potential from unlicensed devices either requires (i) a high degree of conservatism, or (ii) a margin to account for the uncertainty in the assumptions. Neither appears to be the case in the Commission's current analyses.

Furthermore, it is not clear what basis exists for the assumption that, on average, the mobile device antenna provides 6 dB discrimination towards the satellite. Again, it is impossible to accurately predict the antenna performance for devices for which one knows neither the characteristics nor the applications. However, it seems highly unlikely that low power mobile devices will provide any antenna discrimination towards the satellite. Some mobile antennas may provide some directivity in certain directions. However, theoretically, the average directivity of any antenna over all directions must be 0 dBi. Inmarsat therefore believes it is reasonable to assume an antenna discrimination for mobile devices of 0 dBi. Leaving the Commission's other assumptions unchanged, this leads to an average e.i.r.p. from one device of -20.5 dBW. This is 4.4 dB higher than the value assumed by the Commission.

Finally, with regard to the assumption regarding the average fixed device antenna discrimination, the Commission has assumed an average value of 21 dB.[8] While this value appears to be adequate if one assumes that such devices will comply with the antenna standards as given in §101.115 of the Commission's Rules, that does not appear to be a reasonable assumption in this case. Those standards are intended for point-to-point fixed systems which typically make use of large antennas, specifically designed to meet the required performance standards. For the

[8] *See* NPRM at n.74.

C band, the rules also impose a minimum antenna gain of 38 dBi, for which the minimum antenna diameter is about 1.5m. For comparison, this is about twice the size of a DBS receive antenna commonly used today. Inmarsat does not believe that it is realistic to expect that an antenna of such size and performance will be used for unlicensed devices which one would expect to be relatively inexpensive compared with point-to-point radio relay equipment, and which would typically be installed by the users themselves rather than qualified engineers. Indeed, a 1.5m antenna could well present wind-loading and other mounting challenges that would warrant professional installation.

Indeed, since the Commission proposes that the mobile and fixed unlicensed devices would have approximately the same e.i.r.p. limits, it would likely be much cheaper and easier for a user to purchase a "mobile" device with an omnidirectional antenna, and install it in a permanent, fixed location to operate as a point-to-point link. In such a case, it is also reasonable to assume the device would have a 100% duty cycle. It seems unlikely that it would be possible to regulate against such use. For these reasons, Inmarsat believes that it is more realistic to assume that half the "fixed" devices use omni-directional antennas with a maximum an e.i.r.p. of 1000 mW.

The combined effect of the lack of antenna discrimination from mobile devices, and the very likely use of "mobile" devices used for "fixed" applications is shown in the following table:

	Mobile devices duty cycle (10%)				Fixed Devices 100% duty cycle		
EIRP (mW)	50	100	200	1000	2000	4000	1000
Device distribution	30	35	20	5	2.5	2.5	5
Number in simultaneous transmissions at specified e.i.r.p.	3	3.5	2	0.5	2.5	2.5	5
Antenna discrimination to sat (dB)	0	0	0	0	-21	-21	0
e.i.r.p. towards sat (from outdoor devices) (dBm)	21.8	25.4	26.0	27.0	16.0	19.0	37.0

e.i.r.p. towards sat (from indoor devices) (dBm)	11.8	15.4	16.0	17.0	6.0	9.0	27.0
sum indoor and outdoor devices (dBm)	22.2	25.9	26.4	27.4	16.4	19.4	37.4
sum indoor and outdoor devices (mW)	165.0	385.0	440.0	550.0	43.7	87.4	5500.0
aggregate e.i.r.p. towards sat from 200 devices (mW)	7171.1						
ave. e.i.r.p. from one device (mW)	35.9						
ave. e.i.r.p. from one device (dBW)	**-14.5**						

TABLE 5 Average e.i.r.p. per unlicensed device based on Inmarsat assumptions

Hence, the average e.i.r.p. towards the satellite from the unlicensed devices could well be 9.6 dB higher than the value estimated by the Commission.

4.2 Calculation of Maximum Number of Unlicensed Devices

In Appendix B, the Commission calculates the maximum number of unlicensed devices that could be deployed without creating an interference problem for satellite systems. For C band, the calculated number is 53,369,095, and for Ku band, the number of devices is 369,916,129. Even using the same assumptions as the Commission, Inmarsat has been unable to reproduce the numbers presented by the Commission, and therefore considers that there could be an error or that an additional factor has been taken into account that is not described in the NPRM.

Using the same assumptions as the Commission (and not withstanding our concerns with many of those assumptions), Inmarsat has calculated approximately the same number of "Allowable number of emitters/satellite beam." However, from this parameter, Inmarsat calculates much smaller values for the total number of unlicensed devices within CONUS, as shown in the following table:

Allowable Emitters		**C band**	**Ku band**
Allowable number of emitters/satellite beam	#	171544	739832
Available Bandwidth per satellite beam	MHz	175	500
Part 15 Reuse bandwidths in FSS band	MHz	11.67	25
Alternate polarizations	#	2	2
Total number of unlicensed systems within CONUS		**4,002,693**	**36,991,600**

TABLE 6 Maximum number of unlicensed devices, using the Commission's assumptions

In the C band case, the difference in Inmarsat's results and the Commission's figure is equivalent to 11.2 dB. In the Ku band case, the difference in Inmarsat's results and the Commission's figure is equivalent to 10 dB. Inmarsat therefore respectfully requests that the Commission re-examine its calculations and identify any other factors it may have considered that are not part of the record.

In the table below, Inmarsat calculates the total number of unlicensed devices following the same tabular format as the Commission. Inmarsat uses the same parameters as the Commission with regard to the satellite characteristics, but instead assumes a ΔT/T of 1.5% (as discussed above), for fixed and mobile unlicensed devices in a band with a suitable co-primary allocation. Inmarsat uses the same assumptions for the unlicensed devices as shown in Table 5, which leads to an average e.i.r.p. towards the satellite of -14.5 dBW. This analysis produces the following results:

	Item	Units	Ext.C	Ext.Ku
Upper Frequency Band		GHz	6.6125	13
	Lower Band limits	MHz	6525	12750
	Upper Band limits	MHz	6700	13250
	Wavelength	m	0.045	0.023
	Effective Area Isotrope	dBm^2	-37.86	-43.73
FSS System Parameters				
	Percent of CONUS in one beam	%	75	100
	FSS Satellite uplink antenna gain	dBi	32.3	31.1
	Typical satellite receive temperature	K	500	625
	FSS satellite transmission gain	dB	-5	5
	Typical earth station receive temperature	K	90	100
	Equivalent satellite link noise temp	K	248.11	2076.42
Allowable Part 15 Device (Delta T/T)(co-primary allocation)		%	1.5	1.5
Satellite system parameters				
	Allowable increase in equivalent sat link noise temp	K	3.72	31.15
	FSS satellite transmission gain	dB	-5	5
	Allowable increase in Sat noise temp	K	11.77	9.85
	Boltzman constant	dBW/Hz	-228.60	-228.60

		K		
	Allowable interference power @ output of sat antenna	dBW/Hz	-217.9	-218.7
	FSS satellite uplink antenna gain	dBi	32.3	31.1
	Nominal Free space loss	dB	200.26	206.13
	Allowable interference at earth surface	dBW/Hz	-49.93	-43.64
Interference temp system parameters				
	Transmit EIRPs from aggregate interfering devices	dBW	-14.5	-14.5
	Assumed transmit bandwidth	kHz	20000	20000
	Part 15 Gain toward sat	dBi	0	0
	Part 15 Power density toward sat	dBW/Hz	-87.51	-87.51
	Allowable interference at earth surface	dBW/Hz	-49.93	-43.64
	Part 15 Power density toward sat	dBW/Hz	-87.51	-87.51
	Allowable emitters per beam in RLAN BW	dB	37.58	43.87
	Allowable emitters per beam in RLAN BW	#	5723.29	24404.28
Allowable Emitters				
	Allowable number of emitters/satellite beam	#	5723.29	24404.28
	Available Bandwidth per satellite beam	MHz	175	500
	Part 15 Reuse bandwidths in FSS band	MHz	11.67	25
	Alternate polarizations	#	2	2
Total number of unlicensed systems within CONUS			**133,582**	**1,220,214**

TABLE 7 Maximum number of unlicensed devices, using Inmarsat assumptions

The results for the potentially acceptable number of devices is significantly less than the numbers presented by the Commission. In the C band case, the difference is equivalent to 26.0 dB. In the Ku band case, the difference is equivalent to 24.8 dB.

4.3 Necessary E.I.R.P. limits on Unlicensed Devices

It is, of course, impossible to accurately predict the number of unlicensed devices that will ultimately exist in the band, particular when the applications for such devices is unclear. However taking as a basis the Commission's implied figure for the potentially acceptable number of devices (53,369,995 in the C band case), it is possible to determine the necessary power limits to be applied to the devices, to protect satellite systems from interference.

To reach the Commission's number of C-band devices of 53,369,995, it is necessary to tighten the "Transmit EIRPs from aggregate interfering devices" by 26 dB, i.e. to

-40.5 dBW. This is not simply a case of subtracting 26 dB from the maximum e.i.r.p. values proposed by the Commission, since the calculation of the aggregate interference power is based on an assumed distribution of e.i.r.p.s, up to and including the maximum e.i.r.p. It would not be realistic to assume that those devices which operate several dBs below the e.i.r.p. limit would also tighten their emissions by 26 dB. In fact, since the resulting e.i.r.p. limit would constrain even the lowest power device envisaged by the Commission, it is more realistic to assume that all devices will operate to the same e.i.r.p. limit. As a consequence, it is necessary to apply a maximum e.i.r.p. of -29.4 dBW (1.15 mW) to all devices to achieve an aggregate e.i.r.p. in the direction of the satellite of -40.5 dBW, as shown in the following table:

	Mobile devices duty cycle (10%)				Fixed Devices 100% duty cycle		
EIRP (mW)	**1.15**	**1.15**	**1.15**	**1.15**	**1.15**	**1.15**	**1.15**
Device distribution	30	35	20	5	2.5	2.5	5
Number in simultaneous transmissions at specified e.i.r.p.	3	3.5	2	0.5	2.5	2.5	5
Antenna discrimination to sat (dB)	0	0	0	0	-21	-21	0
e.i.r.p. towards sat (from outdoor devices) (dBm)	5.4	6.0	3.6	-2.4	-16.4	-16.4	7.6
e.i.r.p. towards sat (from indoor devices) (dBm)	-4.6	-4.0	-6.4	-12.4	-26.4	-26.4	-2.4
sum indoor and outdoor devices (dBm)	5.8	6.5	4.0	-2.0	-16.0	-16.0	8.0
sum indoor and outdoor devices (mW)	3.8	4.4	2.5	0.6	0.0	0.0	6.3
aggregate e.i.r.p. towards sat from 200 devices (mW)	17.7						
ave. e.i.r.p. from one device (mW)	0.1						
ave. e.i.r.p. from one device (dBW)	**-40.5**						

TABLE 8 Maximum e.i.r.p. for unlicensed devices

Since this value is 29.4 dB lower than the e.i.r.p. limit proposed by the Commission for unlicensed mobile devices, and is 35.4 dB lower than the e.i.r.p. limit proposed for unlicensed fixed devices, the applications available for such devices will be extremely limited. On the basis of these results alone, it could be concluded that the band 6525-6700 MHz is unsuitable for the authorization of unlicensed devices.

Furthermore, it is implicit in both the Commission's and Inmarsat's calculations that the frequencies used by the unlicensed devices are evenly distributed across the available spectrum. Of course, this cannot be assured. Where this is not the case, the aggregate interference could exceed the interference criterion in some parts of the band, while being below the interference criterion in other parts of the band. Because most Inmarsat carriers are narrow band (typical occupied bandwidths of the carriers are between about 1 kHz and about 80 kHz), a factor must be included to ensure that all such carriers are adequately protected from interference. In satellite coordination and interference analysis, it is usual to use a reference bandwidth of 4 kHz, as compared to the 175 MHz used by the Commission in its calculations for C band. Where it is not possible to ensure that unlicensed emissions are uniformly distributed across the available band, it is necessary to include an additional margin in the calculations, equivalent to the anticipated peak-to-mean power ratio.

Since the technical characteristics of the unlicensed devices in these bands remains to be determined, no one can judge the significance of this factor. Inmarsat therefore is unable in its calculations to take this factor into account. However, the absence of a margin for this factor and the absence of a standard reference bandwidth in the Commission's analysis highlights the need to conduct further analysis before proceeding with any proposal to allow unlicensed devices in these bands.

For these reasons, the e.i.r.p. limits proposed by the Commission are considerably in excess of the values necessary to protect FSS systems in both C band and Ku band.

There is a even more fundamental problem. There is no way to ensure the many assumptions the Commission makes about unlicensed devices will hold up in the real world. The Commission has appropriately recognized that it is virtually impossible to control the use of unlicensed devices once they enter the market.[9] Under current rules, manufacturers are not responsible for the use or misuse of the devices by end users. And the Commission has no ability to know how many devices are out there, where they are, or how they are used. These facts may not matter in a case where unlicensed devices operate in their own band. But they are critical considerations in any deliberation about the potential impact of unlicensed devices in bands used by licensed services. And they highlight the devastating effect on licensed users if the Commission's assumptions about unlicensed devices prove wrong: there is no way to put the proverbial genie back in the bottle.

5. Satellite Monitoring of Spectrum Occupancy

The Commission proposes the use of the $\Delta T/T$ criterion and its resultant power limits on unlicensed devices as a "first step implementation of the interference temperature concept." With a view to extending the concept to include "adaptive or real-time interference measurement," the Commission suggests in paragraph 50 that "it could be possible for satellites to monitor and make available real-time measured data..." Below, Inmarsat addresses the infeasibility of making the necessary interference power measurements.

Some of Inmarsat's older operational satellites do have a power measuring device installed, which is designed to measure the total output power of each transponder. Inmarsat's more recent generation of satellites have telemetry devices which measure the current drawn by the power amplifiers and which can provide an indirect measurement of the total power in the transponder. However, the effect of interference on the total transponder power is tiny, as illustrated by the following example.

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[9] *See Review of Part 15 and Other Parts of the Commission's Rules*, First Report and Order, 17 FCC Rcd 14063 (2002).

Assume solely for the sake of argument the interference criterion proposed by the Commission ($\Delta T/T = 5\%$) and a transponder for which the carrier to noise ratio is 20 dB. This level of interference leads to an increase in noise + interference power of 0.21 dB and leads to an increase in the total transponder power of 0.002 dB. Hence, to detect an increase in noise at the level proposed by the Commission, the transponder power measuring device would be required to detect a difference in power of 0.002 dB. This is not feasible for two reasons:

1) the required accuracy of the power measuring device significantly exceeds what is currently achievable; and

2) the power in the transponder varies significantly anyway, due to changes in carrier loading, variations in uplink power, etc.

If all carriers in a particular transponder were switched off, only the noise and uplink interference would be present and it would then be necessary to measure an increase in power of 0.21 dB (continuing with the example above). This is not feasible for three reasons:

1) as for the above case, the required accuracy of the power measuring device significantly exceeds what is currently achievable;

2) the noise + interference power in the transponder varies significantly anyway, due to (for example) changes in the uplink interference power from all external sources, fluctuations in the satellite antenna pointing, component aging and the satellite temperature; and

3) to switch off the uplink carriers in an entire transponder which would require for the traffic to be carried in alternative transponders, thereby reducing the overall traffic capacity of the satellite. This would lead to a significant increase in the risk of call blocking and would therefore be commercially unacceptable.

Since measuring the interference at the satellite is not possible, it is necessary to consider the feasibility of measuring the interference at the receiving earth station. At the earth station, it may be feasible to install a receiver to measure the noise + interference power in a small segment of the band, not overlapping with wanted carriers. Although such devices could be technically feasible, there is no means by which the power measured could be separated out into its various components. It is necessary to determine not only the total noise + interference power, but also the uplink interference produced by the unlicensed devices which are subject to the real-time monitor and control approach. This interference power would have to be separated unambiguously from all the other noise and interference sources. These other sources include:

1. The earth station receiver noise;
2. The earth station antenna noise;
3. The interference received by the earth stations from terrestrial services in the downlink band;
4. The interference received by the earth station from other satellites;
5. The noise power generated internally by the satellite;
6. The interference received by the satellite from licensed terrestrial devices;
7. The interference received by the satellite from unlicensed terrestrial devices, not subject to the real-time monitor and control approach (as proposed as an interim measure by the Commission in this NPRM);
8. The interference received by the satellite from terrestrial services outside the United States;
9. The interference received by the satellite from other FSS earth stations; and
10. Spurious and adjacent channel interference generated by carriers operating on the satellite.

To compound the difficulty in measuring only interference from the unlicensed devices which are subject to the real-time monitor and control approach, all the above interference sources will show unpredictable temporal power variations to different degrees. Inmarsat is not aware of any method by which the interference from the unlicensed devices which are subject to the real-time monitor and control approach could be distinguished from the other noise and interference sources.

In support of this proposed method of measuring interference, the Commission notes that "satellites are already being used for real-time, remote monitoring of geophysical, meteorological and environmental conditions on the surface of the earth." While this fact is true, it does not support the proposition for which it is cited.

The passive remote sensing satellites to which the Commission refers were built specifically for the purpose of measuring small fluctuations in the naturally occurring noise emitted from the earth's surface or its atmosphere. ITU-R Recommendations SA.515 and SA.1029 give useful descriptions of such devices. The receivers used are designed specifically for the purpose of measuring naturally occurring noise, which is very different to the purpose of receivers used in communication or navigation satellites, which are designed to receive radio signals for purposes of amplification and retransmission. It is notable that passive sensing devices are not capable of distinguishing radio interference from the natural noise which they aim to measure.

In fact, a passive sensor deployed on a geostationary satellite in the band 6525-6700 MHz would itself be particularly vulnerable to interference from FSS uplinks in the same band. Although RR footnote 5.458 states that in the band 6425-7075 MHz, passive microwave sensor measurements are carried out over the oceans, there is no allocation to the earth exploration satellite (passive) service in this band. Therefore, from the international perspective, there would be no means to protect such sensors from interference from FSS networks with small orbital separation. In any case, a passive sensor deployed in this band for the purpose of interference measurement should in no way constrain the development of the FSS. As a consequence, even if such sensors were to be deployed in the bands in question for the purpose of interference measurement, they would receive interference from other interference sources, including interference from FSS earth stations, and they, too, would be unable to distinguish (i) interference from the unlicensed terrestrial devices subject to the real-time monitor and control approach from (ii) all other sources of uplink interference.

In short, Inmarsat believes that making the required interference measurements is not technically possible, either on the ground or in space.

Even if monitoring were technically feasible, each of the identified approaches has cost implications which would need to be considered. If a sensor were to be deployed at the receiving earth station, who would pay for the development and maintenance of the receiver and who would pay for the resulting loss in capacity of the network? If a sensor were to be deployed on a purpose build satellite, who would pay for its development, launch, operational costs, and ground infrastructure? If a sensor were to be deployed on a future FSS satellite, who would pay for the development and manufacture? How would the FSS operator be compensated for the increased weight and complexity of its satellite? Since there is no benefit to the FSS from the introduction of unlicensed devices, it would not be reasonable for costs to be borne by satellite operators.

6. Conclusion

The FSS uplink bands at issue in this proceeding are not suitable for the introduction of the interference temperature concept. The introduction of unlicensed devices with the power limits proposed by the Commission would lead to significant interference to the FSS. Because the operational and technical characteristics of the proposed unlicensed devices in this band have not been fully identified, it simply is not possible to calculate appropriate power limits. Moreover, from Inmarsat's analyses, it is clear that a number of assumptions in the Commission's calculations are not reasonable and some appear unsubstantiated.

Respectfully submitted,

Inmarsat Ventures Ltd

By: __/s/__________

Paul M Deedman
Senior Frequency Coordination Engineer
Inmarsat Ventures Ltd.
99 City Road
London EC1Y 1AX
United Kingdom

John P. Janka
Alexander D. Hoehn-Saric
LATHAM & WATKINS LLP
555 11th Street, N.W., Suite 1000
Washington, D.C. 20004-1304
(202) 637-2200

Its Counsel

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